

example of FIG. 3, thermal management unit 335 compares the temperature information against a programmed temperature threshold. The value of the temperature threshold may be any appropriate value, and it represents temperature of the temperature sensor that is associated with temperature limit of the device skin, such as a temperature that is known to be unsafe or uncomfortable. The value of the temperature threshold will depend on the heat conduction properties of the particular device. For instance, a device with a heat spreading layer built into it may be assigned a higher temperature threshold than a device that allows a more rapid heat transfer from the SOC to the skin. In some scenarios, the temperature threshold may be assigned to a device based upon experimentation and/or known heat transfer properties of the design. As noted above, the temperature threshold may be saved to memory in the processor of the device and accessed by thermal management unit 335 as it performs method 700.

[0060] In alternative embodiment, action 730 may include estimating a device skin temperature using the temperature information. For instance, if there is a known offset (e.g., 10° C.) between the in-package temperature and a skin temperature of the device, the offset may be used to estimate the skin temperature of the device from the temperature information (e.g., by subtracting 10° C. from the in-package temperature). In such an embodiment, the temperature threshold may correspond to a limit of the device skin (e.g., 40° C.). In such an instance, action 730 may include comparing the estimated skin temperature to the skin temperature threshold and determining to mitigate the temperature based on that comparison.

[0061] At action 740, system mitigates the performance of the processor chip in response to the temperature information. For instance, in the example of FIG. 3, thermal management unit 335 compares the temperature information to the programmed threshold. If the temperature information indicates that the temperature of the temperature sensor is greater than the threshold, then the thermal management unit 335 may reduce an operating parameter of the processor chip. An example of a processor chip is SOC 230 of FIG. 2, although the principles described herein may be applied to any appropriate computer processor.

[0062] In one example, the thermal management unit 335 reduces an operating frequency of one or more cores in the SOC, thereby reducing power consumption. However, action 740 may include any appropriate thermal mitigation technique, such as putting cores in an idle state. For instance, in the example of FIG. 3, thermal management unit 335 may send commands to clock control unit 312 to reduce the clock frequency or gate the clock frequency altogether. In fact, reduction of any operating parameter, such as frequency or voltage, is within the scope of embodiments. The process continues to operate as the SOC operates, continually measuring the power consumption and taking appropriate mitigation steps according to the algorithm.

[0063] The scope of embodiments is not limited to the specific method shown in FIG. 7. Other embodiments may add, omit, rearrange, or modify one or more actions. For instance, method 700 may also include functionality to return the clock frequency to a previous level or otherwise to increase the clock frequency when thermal mitigation is no longer desired, such as after determining that the measured temperature has decreased beyond the same or a different threshold. Also, various embodiments may include

taking multiple temperature readings from various temperature sensors spread throughout the package and perhaps the SOC itself. In fact, method 700 does not exclude the use of on-chip temperature readings for other processes.

[0064] Various embodiments may provide one or more advantages over conventional solutions. For instance, it may be difficult to capture a temperature reading directly from the skin of a computing device, especially for more compact and mobile computing devices such as phones and tablets. Nevertheless, skin temperature can be very relevant to a user's perception of comfort. Some conventional solutions use temperature readings gathered from sensors on the processor and base thermal mitigation decisions on that temperature reading. But temperature readings gathered from thermal sensors on the processor may not provide an accurate indication of skin temperature, thereby causing intervention of a thermal mitigation process too early or too often and sacrificing performance of the system.

[0065] By contrast, the systems described herein provide thermal mitigation using temperature readings gathered from one or more temperature sensors physically separate from the chip but nevertheless in the same package as the chip. The physical materials of the package spread the heat produced by the chip and act as a low pass filter, so that a temperature reading from an in-package temperature sensor more closely matches a temperature curve of the device skin as compared to a temperature sensor on-chip. Some embodiments described herein may improve the operation of a processor chip by allowing for more accurate thermal management, thereby providing comfort and safety for human users.

[0066] As those of some skill in this art will by now appreciate and depending on the particular application at hand, many modifications, substitutions and variations can be made in and to the materials, apparatus, configurations and methods of use of the devices of the present disclosure without departing from the spirit and scope thereof. In light of this, the scope of the present disclosure should not be limited to that of the particular embodiments illustrated and described herein, as they are merely by way of some examples thereof, but rather, should be fully commensurate with that of the claims appended hereafter and their functional equivalents.

What is claimed is:

1. A method comprising:

receiving an electrical signal from a temperature sensor, wherein the temperature sensor is disposed within a package including a processor chip, further wherein the temperature sensor is thermally separated from the processor chip by materials within the package;

generating temperature information from the electrical signal;

processing the temperature information to determine that a performance of the processor chip should be mitigated; and

mitigating the performance of the processor chip in response to the temperature information, wherein processing the temperature information and mitigating the performance of the processor are performed by the processor chip.

2. The method of claim 1, wherein generating temperature information comprises: